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IMPACT OF BIOFERTILIZATION AND TWO LEVELS OF FERTILIZERS ON YIELD AND YIELD COMPONENT OF WHEAT (*TRITICUM AESTIVUM*) UNDER DROUGHT CONDITION

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Abstract

Plants, during the period of growth and development, are exposed to environmental stress. One of the most important stresses is draught stress. The objective of this study was to evaluate the effect of bio-fertilizer (*Azotobacter* and Mycorrhizae) inoculate under drought stress condition on yield and yield component of wheat plant (*Triticum aestivum* L.).Therefore, Field experiment was conducted during 2018- 2019 in loam soil at the research field of the Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq, to study the effect of bio-fertilizers and two levels of chemical fertilization (50% and 100%) in yield and yield component of wheat *Triticum aestivum* L. cultivar IPA 99 by the genus *Azotobacter chroococum* (Azoto) and *Glomus mosseae* (AMF) singly each of them, or in combination under drought condition. The results revealed that the application of bio-fertilizers reduced the negative impacts of water deficit. However, (*Azotobacter* + *Glomus mosseae*) treatment was significantly increased the means of yield component (length spike, number of spike in m^2, and 1000 grain weight) (11.49 cm, 382.0 spike.m^2, and 29.27 g), respectively. Also increased grain yield and biological yield (4.17 t.ha^{-1}, and 16.35 t.ha^{-1}) respectively, compared to the control treatment at 20% water deficit and 50% fertilization. Besides, there was no antagonism between *A. chroococcum* and *Glomus mosseae*, which can recommend to use them as bio-fertilizer. Finally, the bio-fertilizer (*Azotobacter* + *Glomus mosseae*), had the maximum impact on yield; and that can decrease use of chemical fertilizers through using of biological fertilizers and to reach to the same yield with use only 50% chemical fertilizers under water defected condition.

***Keywords*: Bio-fertilizers, *Azotobacter* sp., *Glomus mosseae*, Wheat, drought conditions

Introduction

Wheat (*Triticum aestivum* L.) is the most extensively grown cereal crop in the world, covering about 237 million hectares annually and accounting for a total of 420 million tones (Badr Eldin *et al.*, 2017) and for at least one-fifth of man's calorie intake (Oyewole *et al.*, 2005). The crop is usually sown between November/December to be harvested March/April. The optimum time for seed sowing is mid-November. Sowing earlier or later than Mid-November will affect yield in wheat crop (GAIN, 2014).

Mycorrhiza is the name of the very important relationship between plant roots and certain types of fungi, the plant provides the fungi with carbohydrates and in exchange , the fungi increase the plant's ability to up take phosphorus and micronutrients from the soil and provide protection from certain root diseases (Abdelmoneim, 2014). Th *Glomus mosseae* reproduce asexually by spore production. There is no evidence that AMF reproduce sexually (Pagano *et al.*, 2016). In this context, and because Vesicular-arbuscular mycorrhizal, fungi are known to enhance the ability of the plants to establish and cope with stress situations (nutrient deficiency, drought, etc.), the use of these fungi as plant inoculants, was investigated to help plants to thrive in degraded arid / semiarid areas (Allen and Allen, 1980) While drought responses in mycorrhizal crop plant species have received considerable attention (Alguacil *et al.*, 2003; Auge, 2004) . Yet, physiological responses during drought recovery are still poorly studied.

Azotobacter, a gram negative, free living and plant growth promoting rhizobacteria, was first reported by Kloepper and Schroth (1978). It's used as a bio-fertilizer for the first time by Gerlach and Voel (1902) with the purpose of supplementing soil-N with biologically fixing N_2 due to the activity of this bacterium, Since then they have been reported to play a multifaceted role in stimulating the growth of plants not only by fixing atmospheric N_2 under free living conditions but also possess other plant growth-promoting activities like phosphate solubilization, production of plant growth like auxins, gibberellins, cytokinins, in addition to, vitamins and amino acids (Damir *et al.*, 2011; Dey *et al.*, 2017). AM fungi and bacteria can interact synergistically stimulate plant growth through a ray of mechanisms that include improved nutrient acquisition and inhibition of fungal plant pathogens (Abohatem *et al.*, 2011). Drought stress is one of the major limitations to crop productivity so high- yielding crops even in environmentally stressful conditions are essential, Drought affects morphological, physiological, biological and molecular processes in plants resulting in growth inhibition (Rachana *et al.*, 2012). Chemical fertilizer is often synthesized using the Haber–Bosch process, which produces ammonia as the end product (Patil, 2010). This ammonia is used as a feed stock for other nitrogen fertilizers, such as anhydrous ammonium nitrate and urea (Jen-Hshuan, 2006). These concentrated products may be diluted with water to form a concentrated liquid fertilizer, The main macronutrients present in inorganic fertilizer were nitrogen, phosphorus and potassium which influence vegetative and reproductive phase of plant growth (Lindemann and Glover, 2008).

To increase crop yields, it is necessary to apply chemical fertilizer, which have several negative side effects. Chemical fertilizer is extensively used in current agriculture. However, excessive use of chemical fertilizer in agriculture has led to deteriorating human health, environmental pollution (Dixon *et al.*, 2009).

The objective of this study was to evaluate the impact of Bio-fertilizer (*Azotobacter* and mycorrhiza) (Azoto+ AMF) inoculate and chemical fertilizer in different levels (50% and 100% of recommended dose) under drought stress condition on yield and yield component of wheat plant (*Triticum aestivum* L.)

Material and Methods

Soil collection

Four soil samples were collected from wheat and barley fields suffering from drought in Al Ramadi; samples were picked from (10–15) cm below the surface from Rhizosphere of roots of two crops (wheat and barley),which collected in March 2018 in pored polythene bags and stored at room temperature to use for AM fungi and *A. chroococcum* isolation.

Isolation and identification of AM fungi from root -soil mixtures

The spores of AM fungi were isolated by using the wet sieving and decanting method describes by (Gerdemann and Nicolson, 1963). The procedure used was as following:

- The root-soil mixture was vigorously mixed with a glass rod for 30 sec.
- Leave the mixture 10 sec to settle heavier particles and organic material, the remaining soil-root-hyphae-spores suspension is slowly poured through a set of three sieves. The sieves used are those with pores of diameters of 85, 65, and 25 µ respectively.
- The extract was washed away from the sieves to petri dishes of 10cm diameter.
- Using a dissecting microscope, spores, aggregates, and sporocarps were picked by means of pipette.

The fresh spores were used for identification based on morphology of spores, spore –bearing structures, sporocarps morphology (Powell and Bagyaraj, 2000).

Isolation of *Azotobacter chroococcum* from Soil

- Grad dilutions preparation of soil solution (3-10 , 5-10) for each sample.
- One ml from each dilution was placed in 250 ml flask containing 50 ml of N-free Jensen's broth and incubated at 30º C for 2-5days.
- The flasks were examined for a film of surface growth formation, and prepared a wet mount preferably of the surface film and observed with compound microscope .
- Plates of N – free Jensen's agar were streaked and incubated at 30 º C for 1-2 days.
- The plates were examined for colonies presence, the colonies wet mounted and gram stain examined .
- The pure colonies were examined and used as inoculums for a slant of N-free Jensen's agar medium.
- All the isolates of Azotobacter sp. were subjected to biochemical characterizations : Gram stain reaction, Growth on N-free medium containing 1% (sucrose, mannitol, and rhamnose) as a sole carbon sources (Ahmed *et al*., 2005).

Field experiment

Experiment was conducted on (2018-2019) at the research field of the Department of Biology, College of Science, Baghdad University, Baghdad, Iraq. The chemical and physical characteristics of field soil were measured in laboratory of soil Department, college of agriculture, University of Baghdad (Table 1). Field plots (48 plots) (1×2 m) were prepared in the field equipped with rain fall transparent shed to avoid rain fall during winter season. The plots were separated from each other by a plastic sheet inserted vertically in the soil to 35 cm depth in order to prevent the possible horizontal movement of irrigated water and inoculant. grains of wheat cultivar (IPA 99) were sown manually in their respective plots in rows of two meter each with a distance of 20 cm between rows (3 rows per plot) and at seed rate of 10g per row (100 kg/ha). The plot was treated with bio-fertilizer consisted of *Glomus mosseae* , *Azotobacter chroococcum* separately or in combination. Chemical fertilizers (Chf) used were urea (25 kg/ Acers) and super phosphate (P_2O_5) at 100 kg ha^{-1}. All phosphorus fertilizer was added before seeds planting, while urea was divided into two equal amounts. The first amount(50%) was added during the land preparation prior to planting, the second (100%) was added 40 days after sowing (during the early tillering stage).The seeds of wheat *Triticum aestivum* L. cultivar (IPA 99) were sowed (on 28 November 2018). Water stress was applied by irrigated the plots to the soil filed capacity then withheld next irrigation until the soil moisture reached 50, and 20 % of soil field capacity. All weeds were hand weeded during the course of study. Soil moisture of the plots was recorded by weight basis method (Standards Association of Australia, 1977).

Results

Physical and chemical properties of soil

The results of soil analysis revealed that the soil texture was loam with EC 1.1 and pH 7.4 (Table 1) N, P and K available were 14.58, 24.36 and 375.16 mg. kg^{-1} respectively.

Yield Components

(a) Length of spike

The variance analysis (table 2) shows that the spike length significantly affected by water deficit at different fertilization levels. The highest mean of the spike length was 13.05 cm of the 50% water deficit, while the lowest was 11.36 cm of the 20% water deficit. Besides, the highest mean of spike length was 12.60 cm at 100% fertilization, but the lowest was 11.81 cm at 50% fertilization. Hence, the interaction between the fertilization and water deficit were significantly affected, the highest mean was 13.41 cm at 100% fertilization and 50% water deficit, while the lowest was 10.92 cm at 50% fertilization and 20% water deficit.

Also, the result of the interaction between the fertilization and the bio-fertilizers were significantly affected, the highest value was 13.14 cm of Azoto +AMF at 100% fertilization, while the lowest was 10.77 cm of control at 50% fertilization. Moreover, the interaction between water deficit and bio-fertilizers were significantly affected, the highest value was 13.64 cm of Azoto +AMF at 50% water deficit, but the lowest was 10.35 cm of control at 20% water deficit.

Furthermore, the triple interaction between fertilization, water deficit and bio-fertilizers were significantly affected. the result in table 2 showed that the highest value was 13.93 cm of Azoto +AMF at 100% fertilization and 50% water deficit, while the lowest was 9.92 cm of control at 50% fertilization and 20% water deficit.

(b) Number of spikes in m²

The interaction between the fertilization and bio-fertilizers were significantly affected. Table 3- showed that the highest value was 470.27 spikes.m^2 of Azoto +AMF at 100% fertilization, while the lowest was 389.02 spikes.m^2 of control at 50% fertilization. Although, the highest mean of spikes in m^2 was 442.80 spikes.m^2 at 100% fertilization, but the lowest was 411.49 spikes.m^2 at 50% fertilization.

As well as, the interaction between the fertilization and water deficit were significantly affected, the highest mean was 490.53 spikes.m^2 at 100% fertilization and 50% water deficit, while the lowest was 356.66 spikes.m^2 at 50% fertilization and 20% water deficit. Also, the highest mean between the treatments was 450.44 spikes.m^2 of Azoto +AMFcompared with bio-fertilizers control was recorded the lowest number of spikes per m^2 with 396.21 spikes.

In addition to, the interaction between water deficit and treatments were significantly affected, the highest value was 476.71 spikes.m^2 of Azoto +AMF at 50% water deficit, but the lowest was 339.44 spike.m^2 of control at 20% water deficit. Although, the triple interaction between fertilization, water deficit and bio-fertilizers were significantly affected, the highest value was 514.25 spikes.m^2 of Azoto +AMF at 100% fertilization and 50% water deficit, but the minimum value was 334.40 spikes.m^2 of control at 50% fertilization and 20% water deficit.

(c) 1000 grain weight

Results in Table 4 shown that means weight of 1000 grain significantly affected by water deficit stress at different fertilization levels. The highest mean of 1000 grain weight was 35.82 g for the 50% water deficit, while the lowest was 28.28 g for the 20% water deficit. In addition to, the highest mean of 1000 grain weight was 33.77 g at 100% fertilization, but the lowest was 30.32 g at 50% fertilization. Otherwise, the highest mean between the bio-fertilizers was 34.54 g of Azoto +AMF, while the lowest was 27.35 g of control.

Although, the interaction between the fertilization and water deficit were significantly affected, the highest mean was 37.63 g at 100% fertilization and 50% water deficit, while the lowest was 26.65 g at 50% fertilization and 20% water deficit. As well as, the interaction between the fertilization and the treatments were significantly affected, the highest value was 36.02 g of Azoto +AMF at 100% fertilization but the lowest was 25.76 g of control at 50% fertilization.

Also, the interaction between water deficit and treatments were significantly affected, the highest value was 38.47 g of Azoto +AMF at 50% water deficit, while the lowest was 23.65 g of control at 20% water deficit.

Finally, the interaction between fertilization, water deficit and treatments were significantly affected, the highest value was 40.10 g of Azoto +AMF at 100% fertilization and 50% water deficit, while the lowest was 21.77 g of control at 50% fertilization and 20% water deficit.

Grain yield

The interaction between the fertilization levels and water deficit were significantly affected, the highest mean was 5.63 $t.ha^{-1}$ at 100% fertilization and 50% water deficit, while the lowest was 3.85 $t.ha^{-1}$ at 50% fertilization and 20% water deficit. As well as, the highest mean of the grain yield was 5.40 $t.ha^{-1}$ at 50% water deficit, but the lowest was 4.08 $t.ha^{-1}$ at 20% water deficit.

On the other hand, there was significant affected between fertilization, the highest mean of the grain yield was 4.97 $t.ha^{-1}$ at 100% fertilization, but the lowest was 4.50 $t.ha^{-1}$ at 50% fertilization. Hence, the highest mean between the treatments was 5.08 $t.ha^{-1}$ of Azoto +AMF, while the lowest was 4.21 $t.ha^{-1}$ of control.

Furthermore, the interaction between the fertilization and the bio-fertilizers were significantly affected, the highest value was 5.36 $t.ha^{-1}$ of Azoto +AMF at 100% fertilization, while the lowest was 4.10 $t.ha^{-1}$ of control at 50% fertilization. Besides, the interaction between water deficit and treatments were significantly affected, the highest value was 5.74 $t.ha^{-1}$ of Azoto +AMF at 50% water deficit, but the lowest was 3.63 $t.ha^{-1}$ of control at 20% water deficit.

Nevertheless, the triple interaction between fertilization, water deficit and treatments were significantly affected, the highest value was 6.08 $t.ha^{-1}$ of Azoto +AMF at 100% fertilization and 50% water deficit, while the lowest was 3.47 $t.ha^{-1}$ of control at 50% fertilization and 20% water deficit.

Biological yield

Results in table 6 revealed that biological yield significantly affected by water deficit at different fertilization treatments. The greatest mean of the biological yield was 19.54 $t.ha^{-1}$ for the 50% water deficit, while the lowest was 15.77 $t.ha^{-1}$ for the 20% water deficit. Besides, the highest mean of the biological yield was 18.22 $t.ha^{-1}$ at 100% fertilization, but the lowest was 17.09 $t.ha^{-1}$ at 50% fertilization. Hence, the interaction between the fertilization and water deficit were significantly affected, the highest mean was 20.04 $t.ha^{-1}$ at 100% fertilization and 50% water deficit, while the lowest was 15.14 $t.ha^{-1}$ at 50% fertilization and 20% water deficit.

Also, the interaction between the fertilization and the treatments were significantly affected, the highest value was 19.27 $t.ha^{-1}$ of Azoto +AMF at 100% fertilization ,while the lowest was 15.39 $t.ha^{-1}$ of control at 50% fertilization. Moreover, the interaction between water deficit and treatments were significantly affected, the highest value was 20.59 $t.ha^{-1}$ of Azoto +AMF at 50% water deficit, but the lowest was 13.86 $t.ha^{-1}$ of control at 20% water deficit.

Furthermore, the triple interaction between fertilization, water deficit and treatments were significantly affected. the result in table 6 showed that the highest value was 21.28 $t.ha^{-1}$ of Azoto +AMF at 100% fertilization and 50% water deficit, while the lowest was 13.18 t.ha-1 of control at 50% fertilization and 20% water deficit.

Table 1 : Some physical and chemical properties of experiment soil

Available nutrients mg. kg^{-1}			EC ds/m	pH	Field capacity	Soil texture	Clay (g/kg soil)	Silt (g/kg soil)	Sand (g/kg soil)
K	P	N							
375.16	24.36	14.58	1.1	7.4	31	Loam	250	430	320

Table 2 : Effect of Fertilizer levels , Water a viability and AMF and *Azotobacter chroococum* in length of spike

Chf: Fertilizer %	H: Water %	T: Treatments				Chf x H	Mean of Chf H
		AMF	Azoto	Azoto + AMF	Control		
50	20	11.07	11.22	11.49	9.92	10.92	11.81
	50	12.62	13.21	13.36	11.62	12.70	
100	20	11.92	12.12	12.36	10.77	11.79	12.60
	50	13.55	13.71	13.93	12.50	13.41	
LSD	--	LSD Chf HT = 0.733 *				LSD Chf H= 0.544 *	
Chf x T		LSD Chf T = 1.106 *				Mean of Chf	
Chf: 50		11.84	12.21	12.42	10.77	11.81	LSD F= 0.118 *
Chf: 100		12.71	12.92	13.14	11.64	12.60	
H x T						Mean of H	
H: 20		11.50	11.67	11.93	10.35	11.36	
H: 50		13.06	13.46	13.64	12.06	13.05	
LSD		LSD HT = 0.555 *				LSD H= 0.118 *	
Mean of T		12.28	12.56	12.78	11.20	LSD T= 0.167 *	
* (P<0.05).							

* = significant of 5%

Table 3 : Effect of Effect of Fertilizer levels, Water a viability and AMF and *Azotobacter chroococum* in number of spike.m^2

Chf: Fertilizer %	H: Water %	T: Treatments				Chf x H	Mean of Chf H
		AMF	Azoto	Azoto + AMF	Control		
50	20	350.18	359.97	382.0	334.40	356.66	411.49
	50	469.12	473.38	479.16	443.64	466.32	
100	20	399.45	410.08	426.27	344.48	395.07	442.80
	50	488.41	410.08	514.25	462.32	490.53	
LSD	--	LSD Chf HT = 19.464 *				LSD Chf H= 18.75 *	
Chf x T		LSD Chf T = 66.45 *				Mean of Chf	
Chf: 50		409.65	416.68	430.63	389.02	411.49	LSD F= 4.053 *
Chf: 100		443.94	453.62	470.27	403.40	442.80	
H x T						Mean of H	
H: 20		374.82	385.03	404.19	339.44	375.87	
H: 50		478.77	485.27	496.71	452.98	478.43	
LSD		LSD HT = 23.17 *				LSD H= 4.053 *	
Mean of T		426.79	435.15	450.44	396.21	LSD T= 5.73 *	
* (P<0.05).							

* = significant of 5%

Table 4 : Effect of Effect of Fertilizer levels , Water a viability and AMF and *Azotobacter chroococum* in in 1000 grain weight (g)

Chf: Fertilizer %	H: Water %	T: Treatments				Chfx H	Mean of Chf H
		AMF	Azoto	Azoto + AMF	Control		
50	20	27.52	28.05	29.27	21.77	26.65	30.32
	50	34.16	35.22	36.84	29.74	33.99	
100	20	30.98	31.21	31.94	25.52	29.91	33.77
	50	38.74	39.33	40.10	32.37	37.63	
LSD	--	LSD Chf HT = 3.190 *				LSD Chf H= 2.45 *	
Chfx T		LSD Chf T = 4.88 *				Mean of Chf	
Chf: 50		30.84	31.63	33.05	25.76	30.32	LSD F= 0.420 *
Chf: 100		34.86	35.27	36.02	28.95	33.77	
H x T						Mean of H	
H: 20		29.25	29.62	30.60	23.65	28.28	
H: 50		36.45	37.27	38.47	31.06	35.82	
LSD		LSD HT = 2.36 *				LSD H= 0.421 *	
Mean of T		32.85	33.45	34.54	27.35	LSD T= 0;595 *	
* (P<0.05).							

* = significant of 5%

Table 5 : Effect of Effect of Fertilizer levels, Water a viability and AMF and *Azotobacter chroococum* in grain yield (t.ha^{-1})

Chf: Fertilizer %	H: Water %	T: Treatments				Chf x H	Mean of Chf H
		AMF	Azoto	Azoto + AMF	Control		
50	20	3.84	3.92	4.17	3.47	3.85	4.51
	50	5.19	5.32	5.41	4.74	5.16	
100	20	4.30	4.50	4.65	3.78	4.31	4.97
	50	5.68	5.94	6.08	4.84	5.63	
LSD	--	LSD ChfHT = 0.461 *				LSD FH= 0.302 *	
Chf x T		LSD ChfT = 0.853 *				Mean of Chf	
Chf: 50		4.51	4.62	4.79	4.10	4.50	LSD Chf= 0.057 *
Chf: 100		4.99	5.22	5.36	4.31	4.97	
H x T						Mean of H	
H: 20		4.07	4.21	4.41	3.63	4.08	
H: 50		5.43	5.63	5.74	4.79	5.40	
LSD		LSD HT = 0.332 *				LSD H= 0.057 *	
Mean of T		4.75	4.92	5.08	4.21	LSD T= 0.081 *	
* (P<0.05).							

* = significant of 5%

Table 6 : Effect of Effect of Fertilizer levels, Water a viability and AMF and *Azotobacter chroococum* in biological yield (t.ha^{-1})

Chf: Fertilizer %	H: Water %	T: Treatments				Chf x H	Mean of ChfH
		AMF	Azoto	Azoto + AMF	Control		
50	20	15.26	15.78	16.35	13.18	15.14	17.09
	50	19.14	19.54	19.90	17.60	19.04	
100	20	16.74	19.54	19.90	14.54	16.41	18.23
	50	20.16	20.92	21.28	17.81	20.04	
LSD	--	LSD ChfHT = 3.352 *				LSD ChfH= 0.993 *	
Chfx T		LSD FT = 2.42 *				Mean of Chf	
Chf: 50		17.20	17.66	18.12	15.39	17.09	LSD Chf= 0.057 *
Chf: 100		18.45	19.01	19.27	16.17	18.22	
H x T						Mean of H	
H: 20		16.01	16.43	16.81	13.86	15.77	
H: 50		19.65	20.23	20.59	17.70	19.54	
LSD		LSD HT = 0.798 *				LSD H= 0.124 *	
Mean of T		17.83	18.33	18.70	15.78	LSD T= 0;176 *	
* (P<0.05).							

Discussion

Rhizosphere is a rich habitat of micro-organisms and should be explored for obtaining potential PGPR, which can be useful in developing bio-inoculants for enhancement of growth and yield of crop plants. Bio-fertilizers inoculations improved yield and yield component of wheat plant. In this study one genus of free living bacteria and fungi were isolated, purified and identified.

The results of field experiment showed that the highest value for yield and yield component was the treatment of (Azoto+AMF) 100% of chemical fertilization. This increasing in yield and yield component in field experiments referred to the action of bio-fertilizers. It is well known that considerable number of bacterial species associated with plant rhizo-sphere are able to exert a beneficial effect upon plant growth and yield such an improvement might be attributed to N-fixing and phosphate solubilizing capacity of bacteria as well as the ability of these microorganisms to produce growth promoting substances such auxin and cytokinins (Ahmed *et al*., 2005). In addition, *Glomus mosseae* can protect host plants against determine effects caused by drought stress and improved acquisition of phosphorus, nitrogen and other growth promoting nutrients (Minaxi *et al*., 2013). Therefore their use as bio-fertilizers for agriculture improvement has been a focus of numerous researchers for a number of years. These results were in agreement with several workers (Egamberdieva, 2010; Milosevic *et al*., 2012).

Results showed that application of chemical fertilizers at two levels increased yield and yield component, specially the full dose (100% chemical fertilizer). These results were in agreement with those obtained by (Das *et al*., 2001; Zahran *et al*., 2002). But the yield will increased when plants inoculated with bio-fertilizers combined with chemical fertilizers, and that because the application of bio-fertilizers which may be attributed to their role by enhancing plant growth due to the availability of different nutrients including N, P and K in addition to several micronutrients (Saharan and Nehra, 2011).

At the end, using bio fertilizers that contain different microbial strains has led to decrease in the use of chemical fertilizers and has provided high quality products free of harmful agrochemicals for human safety.

Conclusions

Under water limited conditions, soil water extraction was a more important component in wheat yield. One of the most important reasons of mycorrhiza protection in drought stress conditions from the host plant is increase of nutrient absorption in soil and better feeding of plant. This fact produced higher values of yield in wheat, which resulted in higher biomass production, higher grain yield and harvest index in wheat under moderate to severe drought stress. Bio-fertilizer could release the decrease effects of drought stress on grain yield of wheat in middle level of drought stress.

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